NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ANALYSIS OF THE OPERATING COSTS FOR LIGHT ARMORED VEHICLES IN THE UNITED STATES MARINE CORPS

by

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December 1998

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December 1998	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE ANALYSIS OF THE OPERATING COSTS FOR LIGHT ARMORED VEHICLES IN THE UNITED STATES MARINE CORPS	5. FUNDING NUMBERS
6. AUTHOR(S) Nickless, Stewart R.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.	

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS Operating Costs, Marine Corps, Light Armored Vechicles	15. NUMBER OF PAGES 81
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

ANALYSIS OF THE OPERATING COSTS FOR LIGHT ARMORED VEHICLES IN THE UNITED STATES MARINE CORPS

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1998

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ACKNOWLEDGEMENT

The researcher would like to thank Dr. Francois Melese, Associate Professor, Defense Resource Management Institute, for providing the funding to conduct the various interviews required for this study.

I. INTRODUCTION

A. GENERAL DESCRIPTION

Within the United States Department of Defense (DOD), the roles and missions of the United States Marine Corps are critical to the fulfillment of the National Security Strategy (NSS). To satisfy its mission, the United States Marine Corps (USMC) has established roles and missions for the Light Armored Vehicle (LAV) that are essential to the success of the NSS. The Marine Corps has procured several variants of LAVs to fulfill the different objectives of amphibious operations. To assess the cost efficiency of the LAV fleet, a better understanding of the LAV's total operating cost is needed. This thesis examines the various cost drivers that contribute to the overall operating cost of the individual variants of the LAV. A framework is proposed for analyzing individual cost drivers for the purpose of establishing the cost to operate the individual variants of the LAV per mile driven. The cost factors examined include replacement parts costs, personnel costs, fuel costs, preservatives, oils and lubricants (POL) costs, Depot Level Maintenance costs, planning and estimating (P&E) costs, depreciation costs as well as miscellaneous costs.

B. BACKGROUND

The initial and continued procurement and upgrade of the Marine LAV as well as its roles and missions have been derived from a complex formulation of

national and military strategy. This strategy is formulated from various sources with the ultimate goal of defending this nation and protecting its national interests.

A hierarchy of Government agencies is responsible for the assignment of roles and missions for which military assets, such as the LAV, are procured in support of those roles and missions. The key players in this hierarchy are the Department of Defense (DOD), the Commission on Roles and Missions, The United States Navy and the United States Marine Corps. The DOD is responsible for establishing a National Military Strategy (NMS) that provides for the defense of the nation and is in keeping with the intent of the NSS. The Commission on Roles and Missions is responsible for establishing the roles and missions of the individual service branches. Once these roles and missions have been established, the individual services must decide which assets will best fulfill those roles and missions.

In Fiscal Year (FY) 1998, the DOD received $250.7 billion in budget authority (BA) with the Marine Corps receiving $10 billion in total obligation authority (TOA). This money will be used to fund all functions of operating the Marine Corps. Of that amount, $2.35 billion, or approximately 23 percent, has been allocated for the operation and maintenance (O&M) of all USMC equipment to include the LAV [Ref. 1].

C. OBJECTIVE

The objective of this research was to determine and document the applicable components that contribute to the operating cost, per mile, for the Light Armored Vehicle. The purpose was to use this knowledge to build a framework to estimate operating costs. This information will be used to assist the Headquarters, Marine Corps, LAV Program Manager and Light Armored Reconnaissance (LAR) Battalion Commanders in budgeting and cost reduction measures.

D. RESEARCH QUESTIONS

The research questions in this thesis step through the process of examining and documenting the direct, indirect, fixed, variable and other cost concepts that should be applied towards determining the overall operating cost per mile for the LAV.

1. Primary Research Question

What is a reliable cost estimation model to predict the total operating cost per mile of the United States Marine Corps' LAVs? This will be established by individual LAV variants as well as for a total operating unit.

2. Secondary Research Questions

1. What costs or cost categories should be included in estimating the operating cost of the LAVs?
2. How should these costs be estimated: as direct or indirect costs?
3. How should indirect costs be allocated for purposes of costing the LAVs?

E. SCOPE AND LIMITATIONS

This thesis documents the costs associated with operating the United States Marine Corps' Light Armored Vehicle variants, focusing on parts replacement data, manpower data, fuel consumption data, and lubricant usage data available and other relevant cost or operating data for the periods from 1992 to 1996. The Air Defense variant of the LAV has been excluded from this thesis due to the lack of historical parts replacement data and data on miles driven. This lack of data is due to the recent procurement of the variant. Additionally, maintenance costs associated indirect personnel and 3rd and 4th echelon maintenance are excluded due to inability to accurately measure these costs.

F. METHODOLOGY

Data was collected primarily through archival research, field research and structured personal or phone interviews. The archival research focused on the cost drivers surrounding the operation of the LAV that are available through manufacturer specifications and test reports, military periodicals, military reports, journals and the Internet. Cost and operational data were gathered from existing reports and documents maintained by the Marine Corps and the Naval Center for Cost Analysis (NCCA). The field research focused on manpower levels and fuel consumption levels at the individual LARs and the structured interviews were used to clarify and supplement the above data and materials. The Marine

Expeditionary Force (MEF) was used as the organization of study because the majority of available data has been presented using MEF units as the metric.

G. ORGANIZATION OF THE STUDY

This thesis is divided into five chapters. Following this introduction, Chapter II provides background information, previous research on the individual variants of LAV, organization of the Marine Corps' combat systems arsenal as well as the mission of the LAV. Chapter III details the methodology of data collection and discusses the various sources of data and the limitations encountered. Chapter IV will provide a detailed analysis of the data gathered and Chapter V will present the summary, conclusions and recommendations.

II. BACKGROUND

A. INTRODUCTION

This chapter will first give a brief background to the problem area and then discuss the origins of the roles and missions of the Marine Corps as they relate to the need for the LAV. Next, it will present background information on previous research available on the subject of formulating the overall operational cost of the LAV family of vehicles (FOV). Following this section, it will give a detailed description of the individual variants of the LAV FOV and finally, a discussion of the structure of the LAV organization within the Marine Corps will be examined.

B. BACKGROUND

The continued support and procurement of the LAV is critical to the fulfillment the roles and missions of the Marine Corps. As the level of budget authority (BA) allocated to the DOD, and the Marine Corps continues to shrink, we must continue to place increased emphasis on cost effectiveness and cost reduction measures. Table 1 presents the changes in the levels of DOD funding since 1988 and Table 2 presents the levels of the Marine Corps' BA since 1985 for the purpose of demonstrating the continual reduction in defense spending and BA for the Marine Corps [Ref. 2]. The figures are presented in current and constant dollars as well as the change in real growth percentage.

Table 2.1. Changes in DOD Spending since 1985

Growth Year	Current Dollars	Constant Dollars	Real Growth %
1988	283.8	378.6	N/A
1989	290.8	373.4	1.4%
1990	292.9	365.4	2.2%
1991	276.2	329.2	11.0%
1992	281.9	329.6	-0.1%
1993	267.4	303.8	8.5%
1994	251.4	279.1	8.8%
1995	255.7	278.4	0.3%
1996	254.4	271.3	2.6%
1997	257.9	269.1	0.8%
1998	254.9	260.1	3.5%

Table 2.2. Changes in USMC BA since 1985

Growth Year	Current Dollars	Constant Dollars	Real Growth %
1988	9.5	12.7	N/A
1989	9.7	12.9	2.1%
1990	9.4	11.7	-10.3%
1991	9.2	11.0	-6.9%
1992	9.6	11.2	2.3%
1993	9.2	10.5	-7.4%
1994	8.6	9.5	-9.5%
1995	8.9	9.7	1.5%
1996	10.3	11.0	11.8%
1997	9.9	10.3	-2.2%
1998	10	10.2	-1.2%

C. ORIGIN OF ROLES AND MISSIONS

The origin of the roles and missions of the Marine Corps and the LAV are the product of key individuals, offices, agencies and activities within the Government. Headed by the President of the United States as Commander-in-Chief of the Armed Forces, the United States Congress has authorized key individuals, offices, agencies and activities to maintain the Armed Forces. These key individuals are responsible for developing the NSS, the NMS and the Roles and Missions of the Armed Forces. Figure 1.1 illustrates the relationship of those individuals, offices, agencies and activities [Ref. 3].

President of the United States

Department of Defense

Commission on Roles and Missions of the Armed Forces

Secretary of Defense

Departments of Navy, U.S. Army and USAF

Chairman, Joint Chiefs of Staff

Joint Chiefs of Staff (Commandant of the Marine Corps)

Figure 1.1. Relationship of Key Players in Establishing Strategies, Roles and Missions

1. The President of the United States

The President of the United States is required by the Goldwater-Nichols Defense Department Reorganization Act of 1986 to establish the NSS for the advancement of the nation's interests. In May 1997, President Clinton published the NSS wherein he identified three core objectives that are essential for advancing the goal of a safer, more prosperous America as follows [Ref. 4]:

1. To enhance our security with effective diplomacy and with military forces that are ready to fight and win.
2. To bolster America's economic prosperity.
3. To promote democracy abroad.

In addition to these three core objectives, the NSS states that "our military forces will have the ability to respond to challenges short of war, and in concert

with regional friends and allies, to win two overlapping major theater wars." [Ref. 5]

2. The Department of Defense

The Department of Defense (DOD) was established under Chapter II of Title 10, United States Code as an executive department of the United States to oversee all aspects of the security of the United States. Since the security of the United States encompasses numerous activities, Title 10 further breaks the DOD into eleven distinct offices/agencies/activities for the purpose of delegating major activities within the department. The following offices/agencies/activities have been created:

1. The Office of the Secretary of Defense (OSD).
2. The Joint Chiefs of Staff (JCS).
3. The Joint Staff.
4. The Defense Agencies.
5. The Department of Defense Field Activities.
6. The Department of the Army.
7. The Department of the Navy.
8. The Department of the Air Force.
9. The Unified and Specified Combatant Commands.
10. Such other offices, agencies, activities and commands as may be established or designated by law or by the President.
11. All other offices, agencies, activities and commands under the control or supervision of any element named in Sections One through Ten [Ref. 6].

3. The Commission on Roles and Missions

In an effort to keep pace with ever-changing roles and missions of the Armed Forces and to ensure the Armed Forces remain effective and efficient in an era of budgetary restraint, Title 10 established the Commission on Roles and Missions of Armed Forces in 1993. The Commission is comprised of eleven private U.S. citizens with diverse military, organizational and management experiences as well as diverse historical perspectives, which are appointed by the Secretary of Defense for the lifetime of the Commission.

The Commission's duties relate to the examination and realignment of the roles and missions of the Armed Forces of the United States. Specifically related to the roles and missions of the United States Marine Corps, the Commission makes recommendations in the two following areas:

1. The functions for which each military department should organize, train and equip forces.
2. The mission of combatant commanders [Ref. 7].

4. The Secretary of Defense

The Secretary of Defense is the principal defense advisor to the President and is responsible for the formulation of general defense policy and policy related to all matters of direct concern to the DOD. Through powers delegated from the President, the Secretary exercises direct authority, control and direction over the DOD. Additionally, in accordance with the Military Force Structure Review Act

that is contained within the National Defense Authorization Act of Fiscal Year 1997, the Secretary of Defense is required to publish a Quadrennial Defense Review (QDR). The QDR is a collaborative effort between the OSD, JCS, military services and combatant commanders to review the posture of the armed forces in an effort to prepare for the future requirements of the military. A key element of the QDR is to pursue a focused modernization effort that ensures tomorrow's forces are as modern and capable as today's forces are [Ref. 8].

5. Service Departments

Title 10 U.S.C. establishes each service department and defines the composition and functions of each. Within Title 10, the Marine Corps is designated as a department of the Navy. For the purpose of this thesis, section 5063 of Chapter 508 defines the composition and functions of the United States Marine Corps. They are as follows:

1. The Marine Corps, within the Department of the Navy, shall be so organized as to include not less than three combat divisions and three air wings, and such other land combat, aviation, and other services as may be organic therein. The Marine Corps shall be organized, trained, and equipped to provide the fleet marine forces of combined arms, together with supporting air components, for service with the fleet in the seizure or defense of advanced naval bases and for the conduct of such land operations as may be essential to the prosecution of a naval campaign. In addition, the Marine Corps shall provide detachments and organizations for service on armed vessels of the Navy, shall provide security detachments for the protection of naval property at naval stations and bases, and shall perform such duties as the President may direct. However, these additional duties may not detract from or interfere with the operations for which the Marine Corps is primarily organized. [Ref. 8]

2. The Marine Corps shall develop, in coordination with the Army and the Air Force, those phases of amphibious operations that pertain to the tactics, techniques, and equipment used by landing forces. [Ref. 9]

3. The Marine Corps is responsible, in accordance with integrated joint mobilization plans, for the expansion of peacetime components of the Marine Corps to meet the needs of war. [Ref. 10]

6. Chairman, Joint Chiefs of Staff

The Goldwater-Nichols Department of Defense Reorganization Act of 1986 establishes the Chairman of the Joint Chiefs of Staff (CJCS) as the senior-ranking member of the Armed Forces. His principal duty is to advise the President of the United States on military matters. He is also responsible for the publication of the NMS. This document conveys the advice of the CJCS and the JCS for the strategic direction of the Armed Forces of the United States. The CJCS uses the guidance from the NSS and the QDR in the formulation of the NMS [Ref. 11].

The NMS calls for the United States to shape the international environment and create favorable conditions for the U.S., to respond to a full spectrum of crises in order to protect our national interests, and to prepare now for an uncertain future [Ref. 12].

7. Joint Chiefs of Staff

The Joint Staff is composed of the equal numbers of officers from the Navy, Army and Air Force, with about twenty percent of the officers allocated to the Navy being Marines. The JCS is responsible for the unified strategic direction

and operation of combatant forces as well as their integration into an effective land, naval and air forces [Ref. 13].

The requirements of the NSS, MNS, QDR as well as the roles and missions of the Navy and Marine Corps have been considered while designing, procuring and fielding the LAV.

D. PREVIOUS RESEARCH AND DATA AVAILABILITY

The subject of formulating the "overall" cost of LAV operation has not received much attention since the introduction of the vehicle into the Marine Corps' combat systems arsenal. However, the LAV operating and support (O&S) costs have. DOD Directive (DODD) 5000.4 mandated that the Navy establish a Visibility and Management of Operating and Support Cost (VAMOSC) program in order to track the O&S costs for major weapon systems under the supervision of the Cost Analysis Improvement Group (CAIG). Secretary of the Navy Instruction (SECNAVINST) 5000.2A has assigned the responsibility for the VAMOSC to the Director of the Naval Center for Cost Analysis (NCCA) [Ref. 14].

Under Navy directive, the Marine Corps has established the Marine Corps Operating and Support Information System (MOSIS) that provides NCCA with historical and verifiable O&S data on Marine Corps fielded weapon systems including the LAV. The specific weapon systems data must be of sufficient quantity and completeness in order to be included in the MOSIS database. MOSIS gathers information from standard Marine Corps Management Information

Systems (MIS) in order to calculate annual O&S costs linked to the combat system's Table of Authorized Material Control Number (TAMCN). A TAMCN is a unique number that is used to identify a specific item within the combat systems arsenal [Ref. 15].

MOSIS data is collected from the historical data recorded in the Asset Tracking for Logistics and Supply Systems II (ATLASS II) MIS. Within the ATLASS II, the Marine Corps Integrated Maintenance Management System (MIMMS) contains data on material consumption by National Stock Number (NSN), level of maintenance activity, labor hours and equipment repair orders for the LAV FOV [Ref. 16].

The data collected from the MIMMS is presented in the Marine Corps Ground Combat Systems Operating and Support Cost Report which presents specific O&S cost data elements on selected ground combat systems annually. The report provides Navy and Marine Corps field commanders, Headquarters Marine Corps, Department of the Navy and other managers with useful data that can be used to justify annual budgets, to justify new system acquisition or upgrades and to relate actual expenditures to levels of readiness [Ref. 17].

E. LAV ORGANIZATIONAL STRUCTURE

The Marine Corps utilizes a combined-arms concept of closely integrated air and ground forces to provide a successful naval presence and ensure the success of power projection operations. In order to accomplish this task, the

Marine Corps utilizes the Marine Air Ground Task Force (MAGTF) as its primary force structure. The Marine Corps specifically tailors its MAGTF forces to meet specified operational and mission requirements. The largest MAGTF is the Marine Expeditionary Force (MEF) which is composed of a division, an aircraft wing and a force service support group [Ref. 18].

There are currently four MEFs in the Marine Corps and they are designated by roman numerals: I Marine Expeditionary Force (I MEF) consists of bases located in California and Arizona; II Marine Expeditionary Force (II MEF) consists of bases located in North and South Carolina; III Marine Expeditionary Force (III MEF) is forward-based in Okinawa and Mainland Japan; and IV Marine Expeditionary Force (IV MEF) is composed of the reserves and located throughout the United States [Ref. 19].

The basic LAV organization is located within the division component of the MEF. This unit is called the Light Armored Reconnaissance Battalion (LAR) and it is comprised of several LAV companies. The number of LARs within a MEF varies according to the mission of the MEF. For the purposes of this thesis, the 1st LAR and 3rd LAR, within the I MEF were used as the sites from which data was gathered to compute the overall operational cost of the LAV per mile driven. These I MEF LAR units were chosen because of their close proximity to the Naval Postgraduate School which allowed for cost efficient data collection within the limited time and travel resources available for this thesis.

F. LAV VARIANTS

The United States Marine Corps currently operates a fleet of 743 LAVs within its ground combat systems arsenal. The LAV was developed to provide the Marine Corps with a highly mobile and survivable anti-armor system that is capable of traversing all terrain types. It has been used to provide reconnaissance, counter-reconnaissance, security operations and combat operations. There are currently seven amphibious variants of the LAV in use by the Marine Corps. However, as mentioned previously, the air-defense variant does not meet the sufficiency criteria for inclusion in the MOSIS and is excluded from the analysis in this thesis.

Each LAV variant utilizes a baseline LAV chassis that is powered by a six-cylinder Detroit Diesel engine and an Allison automatic transmission. All LAV variants have a 71-gallon fuel capacity and a range of approximately 410 miles, which computes to approximately 5.77 miles per gallon (mpg) [Ref.20]. Additionally, all LAV variants have a ground speed of 62 miles per hour (mph) and a swim speed of 6 mph. All assets are capable of being ready for full amphibious operation in three minutes and are air transportable by either the C-130, C-141, C-5 aircraft or the CH-53 helicopter [Ref.21]. The characteristics of the individual variants are as follows:

1. Light Armored Vehicle, Anti Tank (TAMCN: E0942)

The Anti-Tank Vehicle (LAV-AT) variant utilizes a modified M901 weapon station with 2nd Generation Tube-Launched, Optically Sighted, Wire-Guided (TOW) II Anti-Tank Guided Missile capability. It is employed in support of light infantry and reconnaissance forces using its capabilities to engage hardened targets at long range and provide protected anti-armor support. The LAV-AT is also equipped with a M240 7.62mm coaxial machine gun, a M240E1 7.62mm machine gun and, two M257 Smoke Grenade Launchers. The LAV-AT's crew of four consists of a driver, commander, gunner and loader [Ref. 22]. The LAV-AT has a curb weight of 25,000 pounds and a payload of 2,400 pounds for a loaded weight of 27,400 pounds [Ref. 23]. There are currently 95 LAV-ATs in inventory with a replacement cost of $1.252 million each [Ref. 24].

2. Light Armored Vehicle, Command and Control (TAMCN: E0946)

The Command and Control vehicle (LAV-C2) is designed to provide field commanders with the ability to control and coordinate light armored units in all assigned roles to include fire support. The vehicle is equipped with a suite of radios, a portable shelter, and an auxiliary power unit for bivouac operation. Armament of the C2 vehicle includes the M240E1 machine gun and two M257 Smoke Grenade Launchers. The crew consists of seven, which includes the driver and commander as well as five operations/staff personnel [Ref. 25]. The LAV-C2 has a curb weight of 24,840 pounds and a payload of 2,220 pounds for a loaded

weight of 27,060 pounds [Ref. 26]. There are currently 50 LAV-C2s in inventory with a replacement cost of $650,000 each [Ref. 27].

3. Light Armored Vehicle, 25MM (TAMCN: E0947)

The 25 MM LAV (LAV-25) is designed to permit the rapid deployment of troops within the battle area with reduced casualties and fatigue. It also provides accurate and destructive direct fire against enemy personnel, material targets and light armored vehicles. The LAV-25 is armed with a stabilized M242 25mm automatic gun, an M240 coaxial machine gun, an M240E1 machine gun and two M257 Smoke Grenade Launchers [Ref. 28]. The LAV-25 has a crew of three consisting of the driver, commander and gunner and can carry six combat equipped infantrymen. The LAV-25 has a curb weight of 27,600 pounds and a payload of 1,950 pounds for a loaded weight of 29,550 pounds [Ref. 29]. There are currently 409 LAV-25s in inventory with a replacement cost of $900,000 each [Ref. 30].

4. Light Armored Vehicle, Logistics (TAMCN: E0948)

The LAV-Logistics (LAV-L) variant is designed to deliver supplies, fuel, rations and parts to forward-deployed troops and other armored vehicles utilizing its specialized cargo bay and cargo crane. It is armed with the M240E1 machine gun and two M257 Smoke Grenade Launchers [Ref. 31]. The crew of three consists of the driver, commander and crewmember. The LAV Logistics has a curb weight of 22,760 pounds and a payload of 5,440 pounds for a loaded weight

of 28,200 pounds [Ref. 32]. There are 94 LAV-Ls in inventory with a replacement cost of $634,000 each [Ref. 33].

5. Light Armored Vehicle. Mortar (TAMCN: E0949)

The LAV-Mortar (LAV-M) variant is designed to accommodate an M252 81mm mortar from the interior of the vehicle. The vehicle provides indirect fire support to the infantry and reconnaissance forces as well as smoke marking of ground targets for aerial assaults. It is armed with the M240E1 machine gun and the M257 Smoke Grenade Launcher. The LAV-M's crew of 5 consists of a driver, a commander and 3 gunners [Ref. 34]. The LAV-M has a curb weight of 23,400 pounds and a payload of 2,900 pounds for a loaded weight of 26,300 pounds [Ref. 35]. There are 50 LAV-Ms in service, each with a replacement cost of $667,000 [Ref. 36].

6. Light Armored Vehicle, Recovery (TAMCN: E0950)

The LAV Recovery variant has been designed to provide organizational and intermediate levels of repair and recovery services for disabled vehicles. It features a boom crane, winch, spade, compressor, transfer pump and auxiliary power unit for this purpose. This LAV is armed with a M240E1 machine gun and M257 Smoke Grenade Launcher. It has a crew of three, consisting of a driver, commander and rigger [Ref. 37]. The LAV Recovery has a curb weight of 26,900 pounds and a payload of 1,500 pounds for a loaded weight of 28,400 pounds [Ref.

38]. There are 45 LAV-Rs in inventory with a replacement cost of $702,000 each [Ref. 39].

G. SUMMARY

This chapter has provided a brief discussion of the research problem as well as some background information on the origin of the roles and missions that the USMC has adopted for the LAV. Additionally, a detailed description of the LAV variant's background was presented. The next chapter will discuss the research methodology used in preparing this thesis.

III. RESEARCH METHODOLOGY

A. INTRODUCTION

This chapter will present a discussion of the principles of research methodology used in planning of this thesis. Additionally, a discussion of the various methods and sources used as well as those not used in the collection of the data will be presented.

B. BACKGROUND

The need for research questions like the one presented in this thesis originates in the failure of an existing base of knowledge to answer questions or solve problems relating to the operating cost of the LAV. The critical aspect in the success of such research often lies in the nature and proper definition of the problem before attempting to conduct the actual research. The best research questions are characterized by the following attributes [Ref. 40]:

- Properly defined problem that is described and labeled accurately.
- The problem is presented in solvable terms.
- The problem is logically connected to the originating environment and the solution to the problem can be applied to that environment.
- The problem has been evaluated against existing research to ensure its uniqueness.
- The solution to the problem must make a contribution to the existing body of knowledge on the subject.

C. FORMULATION OF RESEARCH QUESTIONS

The process of problem genesis is divided into two basic approaches - the formal approach and the informal.

1. Formal Approaches

Research questions that are generated formally rely on methodical and precise procedures that are based on a well-defined system of analysis. The formal approach is widely used and considered to give superior results. There are several methods that are applied when using the formal approach to formulate a research question and they are as follows [Ref. 41]:

- Research Approach: relies on the existence of prior research that generates new problems worthy of future research.
- Analog Approach: uses the knowledge of one area to formulate a research question in a similar area. The areas under consideration must possess the same characteristics for this method to be effective.
- Renovation Approach: replaces defective elements of a theory in an effort to improve the effectiveness of that theory.
- Dialectic Approach: develops alternate plans for the purpose of challenging existing or proposed theories.
- Extrapolation Approach: concerned with projecting current theories and trends into the future. Typically tries to answer the question "Is there a better method?"
- Morphology Approach: examines the numerous combinations of possibilities when dealing with complex questions.
- Decomposition Approach: breaks a problem down into its component parts.

- Aggregation Approach: takes research results and theories from discrete areas and applies them to broader problem areas in an effort to resolve the problem.

The formal approach was not used in the preparation of this thesis because of the lack of previous research and structured knowledge on the subject of LAV operational costs.

2. Informal Approaches

Research questions that are generated informally are based on subjective and unstructured procedures. While the informal approach is not as accepted as the formal approach, it is recognized as an essential element in formulating research questions. There are several methods that are applied when using the informal approach to formulate a research question and they are as follows [Ref. 42]:

- Conjecture Approach: characterized by the use if intuition and hunches in problem solving.
- Phenomenology Approach: characterized by the formulation of research questions from the occurrence of phenomena.
- Consensual Approach: uses group consensus of the existence of a problem as the basis for the formulation of research questions.
- Experiential Approach: based on past experiences as the source of problems requiring research.

The informal approach was used while generating the research questions asked in this thesis because there is no prior research or structured framework on

which to base the study. The structure used in this thesis was developed through conjecture and study of the available data.

D. MODE

The main consideration when defining the manner or mode in which the research will be conducted is whether the primary focus of the project will be inductive or deductive in nature. Inductive research seeks to gain an answer to a question through the study of the facts related to the question while deductive research seeks to verify answers to research questions through the application of further testing. While most research utilizes some elements of both methods, they tend to be focused on one or the other [Ref. 43]. The author used the inductive mode while preparing this thesis.

E. METHODOLOGY

The selection of the appropriate research methodology is the next step in the framework for conducting research. Methodology is composed of the strategies, domains and techniques used in the generation or testing of theories. Strategy is concerned with the way in which the research is conducted while domain relates to the source and environment of the data. Technique refers to the instruments available for use in locating and analyzing data.

The elements of strategy, domain and techniques are interrelated. The selection of a particular strategy leads to the selection of a specific domain and

technique related to that strategy. The four research strategies available are opinion, empirical, archival and analytical research.

1. Opinion Research

In the performance of opinion research, the researcher uses the views, judgments or appraisals within the domain of individuals or groups. Inside the individual domain, the formal technique of survey research deals with soliciting opinions through the use of questionnaires while the informal technique uses interviews as the primary method of solicitation. The formal technique used with the group domain is refereed to as the Delphi method. This method attempt to seek consensus based on the anonymous opinions of individuals within the area of research. The informal technique associated with the group domain is brainstorming [Ref. 44]. This study of the LAV could not use questionnaires because the author lacked the formal knowledge of the area needed to design the questionnaire.

2. Empirical Research

Empirical research requires the researcher to experience data through their own observation and experience within the domain of a case study, a field study or a laboratory experiment. The formal techniques associated with these domains are observation instruments, time and motion studies as well as simulation respectively. All three domains use observation as the informal technique of data collection [Ref. 45].

For this thesis, data had to be gathered from field sources including databases and field interviews. This information enabled the author to conduct a detailed analysis of the cost to operate the LAV.

3. Archival Research

Archival research deals with the collection of data through the examination of recorded records. These records can be found within the primary, secondary and physical domains. The primary domain consists of original documents or official files and records. The secondary domain deals with data gathered and published by others. The physical domain consists of data stored in the physical environment such as footprints or fingerprints. The formal technique associated with the primary domain is content analysis, which is a technique used to evaluate oral and written communication. The formal technique associated with the secondary domain is sampling. This technique uses portions of the available data as a representation of the whole. Erosion and accretion measures, such as the decay rate of uranium, are the formal techniques used with the physical domain. The informal techniques associated archival research are scanning and observation. The technique of scanning simply requires the researcher to review applicable materials or processes and the observation is the result.

4. Analytic Research

Analytic research involves breaking a problem down into its component parts in an attempt to define the causal relationship between the parts through the

mental abilities of the researcher. This is accomplished within the domain of internal logic, which requires an understanding of philosophy, logic and formal reasoning. Mathematics modeling is used as the formal technique while philosophical argument is used as the informal technique [Ref. 46]. This method was not useful because of the limited knowledge of the structure of the LAV cost data.

F. APPLICATION OF METHODOLOGY

For the purpose of this thesis, the informal approach was used to address the research question due to the lack of a formal research structure of the problem of LAV operational cost and availability of existing databases and technical manuals. Within the categories of the informal approach, the decomposition approach was used to separate and analyze the cost drivers that contribute to the overall cost of operating the LAV per mile driven. This thesis takes the inductive approach in the attempt to define the overall cost of operating the LAV per mile driven based on available data. Extensive empirical research within the primary and secondary domains was conducted in the preparation of this thesis. Additionally, the techniques of content analysis, scanning and observation were used while reviewing the available data.

G. ASSUMPTIONS

Numerous assumptions were made in the preparation of this thesis. The use of 1st and 3rd LARs, with 27 percent of all LAV assets within the USMC, as

the study group assumes that their operations and associated costs are representative of all LARs. Additionally the use of 1998 data in the calculation of the overall operational cost assumes that the data is representative of data that would have been available in 1996.

H. SUMMARY

This chapter discussed the various types of methodology available to researchers as well as the methodology used in the preparation of this thesis. The next chapter will consist of a detailed data presentation and analysis to address the primary and secondary research questions.

IV. DATA PRESENTATION AND ANALYSIS

A. INTRODUCTION

This chapter will discuss the various data elements determined to be components of the overall operating cost of the LAVs located in the 1st and 3rd LARs of the I MEF. The following elements will be discussed and presented:

1. Number of vehicles.
2. Number of miles driven during FY92 through FY96 by variant.
3. Parts replacement costs by variant.
4. Personnel costs.
5. Fuel costs.
6. Preservatives, Oils and Lubricants (POL) costs.
7. Inspect and Replace Only as Needed (IROAN) costs.
8. Planning and Estimating (P&E) costs.
9. Depreciation costs.
10. Miscellaneous costs.

B. LAV QUANTITIES

There are currently 205 LAVs attached to I MEF and they are composed of assets located at the 1st LAR, Camp Pendelton, California and at the 3rd LAR, 29 Palms, California. This population represents over 25 percent of the total LAVs in the USMC. Table 4.1 presents a breakdown of the total number of assets by unit, variant and percentage as of November 1998.

Table 4.1. I MEF LAV Assets

UNIT	1st LAR	2nd LAR	Variant Total	Percentage
Variant				
LAV-25	60	46	106	52%
LAV-R	6	5	11	5%
LAV-C2	10	5	15	7%
LAV-M	8	6	14	7%
LAV-AT	16	12	28	14%
LAV-L	16	15	31	15%
I MEF Total			205	100%

C. MILES DRIVEN

All LARs are required to report the mileage driven by all LAV variants in their unit on a monthly basis. The reports are submitted to the NCCA for inclusion into the cost calculations for the LAV FOV. Table 4.2 details the reported miles driven by all variants located within the I MEF from FY92 through FY96 [Ref. 47]. The table also details the number of vehicles, by variant, located at the unit.

The data shows that the annual average number of miles driven over the five fiscal years by the I MEF is 2,551,898 for all variants. Upon closer inspection, a large variance between the five-year average and actual FY averages appears, especially in FY92 and FY96. The data suggests that there was a continual increase in operational/training commitments of I MEF between FY92

and FY96, which would be directly responsible for the increase in miles driven. Another variance worthy of notice is the difference in miles driven within each variant. This difference is due to the missions that each variant is designed to fulfill, the operating miles associated with those missions and the quantity of assets that are available to fulfill the missions.

Figure 4.1 depicts the number of miles driven per variant as a percentage of average miles driven. Due to the significant difference between the total overall average annual miles (2,551,898) and the actual miles driven during FY96 (3,333,806) and the continued high USMC optempo, the author uses the actual miles driven during FY96 as the baseline for calculations, thus providing the best estimation of overall operational cost.

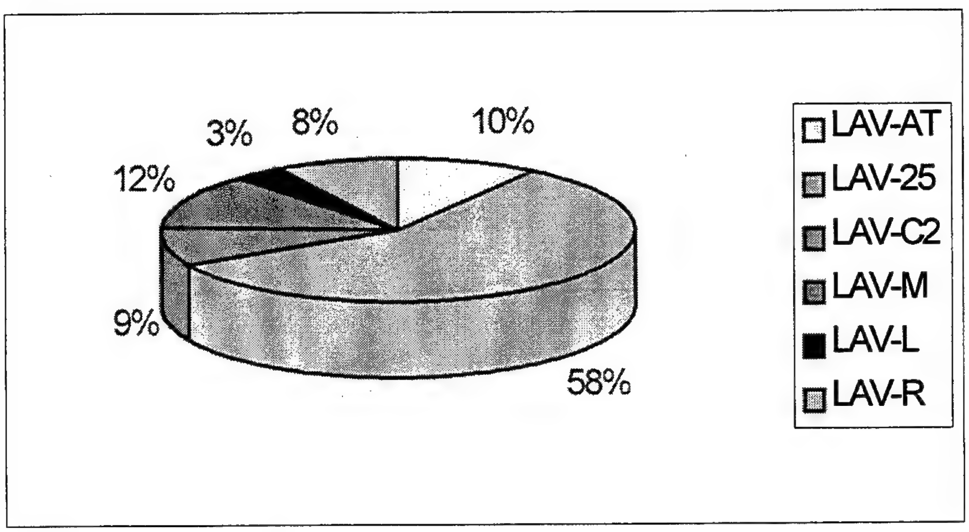

Figure 4.1. LAV Mileage Percentages by Variant

Table 4.2. I MEF LAV Mileage

FY 92	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
QTY	106	28	31	14	15	11	205
AVG MILES/VEH	10,569	224	96	5,423	2,411	8,851	6,532
TOTAL MILES	1,120,314	6,272	2,976	75,922	36,165	97,361	1,339,010
FY 93	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
QTY	106	28	31	14	15	11	205
AVG MILES/VEH	12,321	5,981	3,937	21,333	9,115	18,274	10,888
TOTAL MILES	1,306,026	167,468	122,047	298,662	136,725	201,014	2,231,942
FY 94	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
QTY	106	28	31	14	15	11	205
AVG MILES/VEH	13,392	11,671	3,150	26,319	11,931	18,638	12,666
TOTAL MILES	1,419,552	326,788	97,650	368,466	178,965	205,018	2,596,439
FY 95	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
QTY	106	28	31	14	15	11	205
AVG MILES/VEH	16,731	12,640	3,297	30,997	18,831	28,387	15,894
TOTAL MILES	1,773,486	353,920	102,207	433,958	282,465	312,257	3,258,293
FY 96	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
QTY	106	28	31	14	15	11	205
AVG MILES/VEH	16,932	12,496	3,712	35,757	22,595	21,321	16,262
TOTAL MILES	1,794,792	349,888	115,072	500,598	338,925	234,531	3,333,806

MULTI-YEAR AVERAGE MILES	2,551,898
MULTI-YEAR AVERAGE MILES/VEH	12,448
MULTI-YEAR AVERAGE MILES/VARIANT:	
LAV-25	1,482,834
LAV-AT	240,867
LAV-L	87,990
LAV-M	335,521
LAV-C2	194,649
LAV-R	210,036

D. PARTS REPLACEMENT

Replacement parts for the LAV FOV are available through the Naval Supply System and are identified by part number and National Stock Number (NSN). Parts can be replaced due to scheduled or unscheduled maintenance. The NCCA collects all parts replacement data for use in preparation of the MOSIS report. The FY92 to FY96 parts replacement cost data and averages, by variant are presented in Table 4.3 and Figure 4.2 [Ref. 48]. These costs represent direct, variable costs for all variants.

Table 4.3. I MEF FY Parts Replacement Costs

VARIANT	FY 92	FY 93	FY 94	FY 95	FY 96	FY AVG
LAV-AT	$662,284	$411,519	$223,582	$263,676	$229,619	$358,136
LAV-C2	162,995	142,880	179,479	166,151	85,619	147,425
LAV-25	3,005,540	1,714,197	1,664,018	1,710,418	849,958	1,788,826
LAV-L	231,621	128,661	295,301	182,156	151,053	197,758
LAV-M	122,116	8,906	100,319	134,314	117,854	96,702
LAV-R	0	0	0	121,823	37,214	79,519

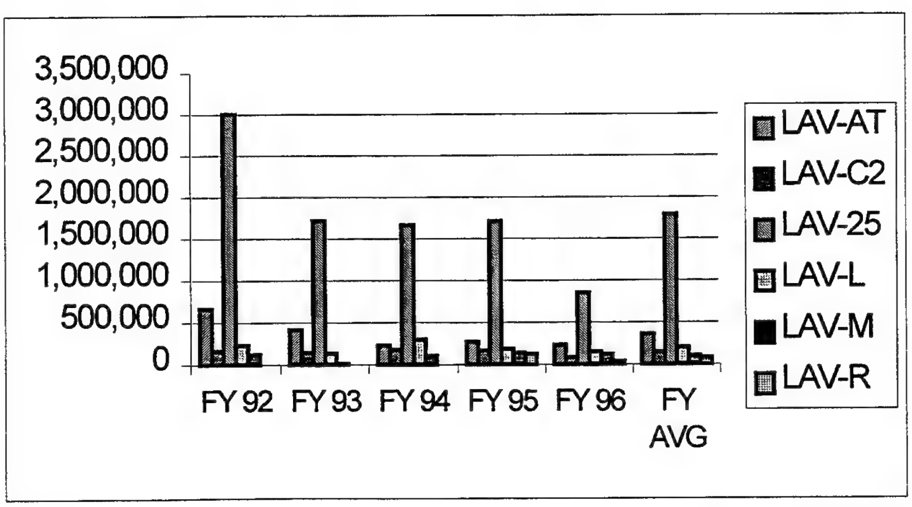

Figure 4.2. I MEF FY Parts Replacement Costs

The data reveals that the LAV-25 has the highest parts replacement costs of all LAV variants and that the LAV-R has the lowest parts replacement costs. The best explanation for the occurrence is due to the quantity of each LAV variant within the I MEF. Table 4.4 compares the cost-quantity relationship in terms of parts cost per vehicle. The LAV-25 and LAV-AT have the highest cost per vehicle while the LAV-L has the lowest parts cost per vehicle. The data indicates there is a wide variation in parts costs across variants.

Table 4.4. LAV Parts Cost-Quantity Comparison

VARIANT	COSTS	QTY	COST/VEHICLE
LAV-25	1,788,826	106	$16,876
LAV-AT	358,136	28	12,791
LAV-L	197,758	31	6,379
LAV-C2	147,425	15	9,828
LAV-M	96,702	14	6,907
LAV-R	79,519	11	7,229

E. PERSONNEL COSTS

This section will examine the various components of determining personnel costs. It will examine the LAR organizational structure, Table of Organization (T/O), Alpha Roster and Regular Military Compensation (RMC) as they apply to the allocation of LAV personnel costs. In this thesis, personnel costs include both direct and indirect costs associated with LAV support. Direct personnel costs include those costs incurred by the efforts of "hands on" personnel such as drivers

and mechanics. Indirect personnel costs are those costs incurred by the efforts of "hands off" personnel such as supply and administrative personnel. To illustrate the impact that personnel costs have on the total operational cost of LAVs, this thesis will present one cost model that considers the affect of personnel costs and one cost model that disregards personnel costs. From a staffing point of view, both direct and indirect personnel costs are fixed costs for the LAR. That is, to operate the LAR to satisfy its mission, these costs remain relatively fixed.

1. LAR Organizational Structure

The organizational structure of a LAR is prescribed by Headquarters, U.S. Marine Corps through the T/O. The T/O for individual units prescribes the organizational structure, billet authorization, personnel strength, and individual assignments. The number of USMC and Navy personnel prescribed by the T/O is used to represent the quantities of personnel that would be utilized in the event of a protracted conflict. Navy personnel are assigned to the LAR to provide medical services to LAR USMC personnel. According to the T/O, each LAR is composed of a Headquarters and Service Company (H&S) and two Light Armored Assault Companies [Ref. 49]. Each is discussed below.

a. Headquarters and Service Company

The Headquarters and Service Company's mission is to provide the battalion with the means for command, control and service support. In order to accomplish this mission it is divided into the following sub-sections [Ref. 50]:

- Battalion Headquarters
- Maintenance Platoon
- Supply Platoon
- Mess Hall
- Motor Transport Platoon
- LAV Platoon Company Headquarters
- Chaplain Section
- Medical Platoon

The T/O for the 1st and 3rd LARs within the I MEF are the same. Table 4.5 lists Marine Corps H&S personnel assigned to the 1st and 3rd LAR, by rank, in accordance with the T/O dated April 4, 1998 [Ref. 51].

Table 4.5. USMC LAR H&S Personnel by T/O

RANK	1ST LAR QTY	3RD LAR QTY	TOTAL
LTCOL	1	1	2
MAJ	3	3	6
CAPT	6	6	12
LT	8	8	16
WO	6	6	12
E9	3	3	6
E8	6	6	12
E7	11	11	22
E6	22	22	44
E5	47	47	94
E4	66	66	132
E3	133	133	266
E2/E1	44	44	88
TOTAL	356	356	712

Table 4.6 lists Navy H&S personnel assigned to the 1st and 3rd LAR, by rank, in accordance with the T/O dated April 4, 1998 [Ref. 52].

Table 4.6. Navy LAR Personnel by T/O

RANK	1ST LAR QTY	3RD LAR QTY	TOTAL
LCDR	1	1	2
LT	2	2	4
E7	2	2	4
E6	5	5	10
E5	9	9	18
E4	23	23	46
E3	27	27	54
TOTAL	69	69	138

b. Light Armored Assault Company

The Light Armored Assault Company's mission is to close with and destroy enemy forces by fire and maneuver, exploiting high mobility, agility and firepower and to conduct reconnaissance, security and economy-of-force missions as may be required. In order to accomplish this mission, it is divided into the following sub-sections [Ref. 53]:

- Company Headquarters
- Logistics Section
- Antitank Section
- 81MM Mortar Section
- Three Light Armored Reconnaissance Platoons

It should be noted that there are four assault companies within the LAR. Table 4.7 lists Marine Corps personnel assigned to the 1st and 3rd Light Armored Assault Companies, by rank, in accordance with the T/O [Ref. 54].

Table 4.7. USMC Light Armored Assault Company Personnel by T/O

RANK	1ST LAR QTY	3RD LAR QTY	TOTAL
CAPT	1	1	2
LT	4	4	8
E8	2	2	4
E6	6	6	12
E5	28	28	56
E4	25	25	50
E3	51	51	102
E2/E1	21	21	42
TOTAL	138	138	276

2. Alpha Roster

In reality, the numbers presented in the T/O do not reflect the actual end strengths that are realized on a day-to-day basis. The T/O represents an ideal personnel structure that is intended to be established in the event of a protracted conflict. The most efficient way to determine the actual number of personnel assigned to a particular unit on a given date is by examining a unit's Alpha Roster. An Alpha Roster is an alphabetical listing of all assigned personnel which, for the purposes of this thesis, includes the rank and date of rank for all personnel. Table 4.8 represents all Navy personnel assigned to the 1st and 3rd LARs on August 18, 1998 by rank. Alpha Rosters are changed whenever personnel either join or leave

a unit, which can be a daily occurrence. Table 4.9 represents all Marine Corps personnel assigned to the 1st and 3rd LARs on August 18, 1998 [Ref. 55].

Table 4.8. Navy LAR Personnel by Alpha Roster

RANK	1ST LAR QTY	3RD LAR QTY	TOTAL
O3	1	2	3
E7	1	1	2
E6	2	1	3
E5	6	4	10
E4	15	18	33
E3	4	10	14
E2	0	2	2
TOTAL	29	38	67

A comparison of the number of personnel assigned by T/O and Alpha Roster, as seen in Table 4.10, reveals that the I MEF is staffed below the numbers indicated in the T/O. Based on the author's experience, this is a common occurrence within the USMC. As a result, the number of personnel indicated by the Alpha Roster will be used in calculating personnel costs because it represents actual personnel on hand vice a notional quantity. Also, the available data did not distinguish between direct and indirect personnel. Therefore, total personnel costs include all personnel costs that are assigned to the LAR. Later, we will consider costing without these costs.

Table 4.9. USMC LAR Personnel by Alpha Roster

RANK	1ST LAR QTY	3RD LAR QTY	TOTAL
LTCOL	1	1	2
MAJ	3	2	5
CAPT	12	11	23
LT	21	26	47
WO	4	5	9
E9	2	1	3
E8	7	9	16
E7	19	14	33
E6	54	44	98
E5	88	85	173
E4	200	234	434
E3	357	293	650
E2/E1	139	71	210
TOTAL	907	796	1703

Table 4.10. I MEF T/O and Alpha Roster Comparison

RANK	T/O	ALPHA
O5	2	2
O4	8	5
O3	24	26
O2/O1	48	47
WO	12	9
E9	6	3
E8	28	16
E7	26	35
E6	102	101
E5	336	183
E4	378	467
E3	728	664
E2/E1	256	212
TOTAL	1954	1770

3. Regular Military Compensation

Military personnel receive pay and allowances based on two factors: their rank and length of time in service. The amount of compensation a service member receives annually can be found in the Regular Military Compensation (RMC) charts that are published annually. RMC "figures combine basic pay, the basic allowance for subsistence and the basic allowance for housing [Ref. 56]" and they represent, as noted earlier, both direct and indirect fixed costs associated with the operation of the LAV.

To approximate the annual total cost of personnel at the 1st and 3rd LARs, it was necessary to calculate the cost for each individual on the Alpha Roster. Therefore, the number of individuals in each rank category and time in service was multiplied by their respective RMC rate. Table 4.11 details the calculations of total personnel costs. The annual total personnel cost for the 1st and 3rd LAR from Table 4.11 is $46,847,511.

Table 4.11. Total Personnel Costs

RANK	YEARS	1st LAR QTY	3rd LAR QTY	RMC	TOTAL
O5	26	0	1	85,015.87	85,015.87
O5	20	1	0	82,785.01	82,785.01
O4	24	1	0	71,323.72	71,323.72
O4	14	1	0	67,169.62	67,169.62
O4	12	0	2	59,154.20	118,308.40
O4	10	1	0	61,879.71	61,879.71
O3E	>=14	1	2	62,257.39	186,772.17
O3	14	0	1	60,334.99	60,334.99
O3	12	0	1	59,154.20	59,154.20
O3	10	1	2	56,914.17	170,742.51
O3	8	6	2	54,640.37	437,122.96
O3	6	3	2	53,247.14	266,235.70
O3	4	2	1	51,465.04	154,395.12

Table 4.11. Total Personnel Costs (cont.)

RANK	YEARS	1st LAR QTY	3rd LAR QTY	RMC	TOTAL
O3	3	0	1	44,377.39	44,377.39
O3	2	0	1	38,497.06	38,497.06
O2E	12	0	1	44,101.83	44,101.83
O2E	10	1	1	50,643.98	101,287.96
O2E	8	1	0	48,815.06	48,815.06
O2	10	1	0	46,159.90	46,159.90
O2	8	0	1	48,815.06	48,815.06
O2	6	2	4	46,159.90	276,959.40
O2	4	6	4	45,472.14	454,721.40
O2	3	2	2	44,377.39	177,509.56
O2	2	2	7	38,497.06	346,473.54
O1E	6	2	0	40,523.45	81,046.90
O1	8	1	0	37,054.41	37,054.41
O1	4	1	2	37,054.41	111,163.23
O1	3	1	0	37,054.41	37,054.41
O1	<2	1	4	31,143.09	155,715.45
CWO3	20	1	1	52,695.37	105,390.74
CWO2	18	0	1	51,244.63	51,244.63
CWO2	12	1	1	43,422.54	86,845.08
CWO2	10	1	1	42,327.05	84,654.10
WO	14	1	1	40,560.83	81,121.66
E9	26	1	0	58,558.10	58,558.10
E9	22	1	0	54,611.12	54,611.12
E9	18	0	1	51,958.01	51,958.01
E8	24	1	1	50,532.27	101,064.54
E8	22	4	0	48,998.78	195,995.12
E8	20	0	4	47,083.55	188,334.20
E8	18	1	3	46,295.15	185,180.60
E8	16	1	1	45,579.64	91,159.28
E7	20	3	3	42,326.85	253,961.10
E7	18	9	9	41,950	755,100.00
E7	16	7	1	41,174.46	329,395.68
E7	14	1	2	40,399.02	121,197.06
E6	>=18	1	7	37,832.52	302,660.16
E6	16	5	4	37,450.31	337,052.79
E6	14	9	15	36,659.93	879,838.32
E6	12	17	8	35,910	897,750.00
E6	10	21	9	34,737.28	1,042,118.40
E6	8	1	2	33,943.98	101,831.94
E6	6	2	0	33,194.60	66,389.20
E5	>=14	2	1	32,734.46	98,203.38
E5	12	2	3	32,350.90	161,754.50
E5	10	6	4	31,592.37	315,923.70

Table 4.11. Total Personnel Costs (cont.)

RANK	YEARS	1st LAR QTY	3rd LAR QTY	RMC	TOTAL
E5	8	13	12	30,847.62	771,190.50
E5	6	25	19	30,129.33	1,325,690.52
E5	4	31	27	29,002.49	1,682,144.42
E5	3	13	17	28,212.92	846,387.60
E5	2	2	6	27,386.89	219,095.12
E4	>=6	8	4	27,060.45	324,725.40
E4	4	26	26	26,407.18	1,373,173.36
E4	3	107	140	25,226.21	6,230,873.87
E4	2	65	67	24,331.54	3,211,763.28
E4	<2	9	16	23,513.27	587,831.75
E3	>=4	8	5	24,045.27	312,588.51
E3	3	36	35	23,456.18	1,665,388.78
E3	2	101	81	22,907.29	4,169,126.78
E3	<2	216	182	22,183.17	8,828,901.66
E2	ALL	127	69	21,492.48	4,212,526.08
E1	>4	1	0	19,834.34	19,834.34
E1	<4	11	4	18,733.24	280,998.60
TOTAL		936	834		46,847,510.65

To calculate the cost of personnel per mile driven, the total personnel costs is divided by the total number miles driven per year as derived in the previous chapter. Indirect personnel costs, such as those associated with the Commandant, USMC and the Commanding General, I MEF, are not included in this thesis due to lack of data on the amount of time these Marines devote to managing LAR issues. Additionally, FY98 personnel costs are used in this calculation because there is no historical data on Alpha Rosters available for comparison. Since the available data makes it impossible to separate the direct and indirect personnel costs, all personnel costs will be treated as direct, fixed costs of the variant fleet but

allocated costs to the individual variant class. Personnel costs will be allocated to the respective variant class based on vehicle percentages calculated in Table 4.1.

F. FUEL COSTS

The cost of diesel fuel to support the operation of I MEF LAV assets represents another direct, variable cost associated with LAV operations. There are several factors that influence the fuel usage that a LAV attains during operation. These factors include the weight of the individual vehicle, the terrain encountered during operation, the aerodynamics of the vehicle and the idle time of the vehicle.

Inspection of the diesel fuel distribution methods of 1st LAR revealed that the LAV variants and support vehicles are fueled on an as needed basis from a filling station located within the LAR maintenance compound. The quantity of fuel dispensed is documented in a logbook for tracking purposes. Inspection of the logbook revealed that the data contained was of little use because of illegible entries. Due to the presence of illegible entries and the use of the fuel by other support vehicles, the miles-per-gallon (mpg) rating for each variant will be used in determining the overall fuel costs.

On December 15, 1988, the System Engineering Management Diesel Division of General Motors of Canada released the final Operating Cost Report for the LAV program. The report provided a fuel consumption rate of 4.8 miles per U.S. gallon of fuel for all variants. The report indicates that the figure was derived from observations made during LAV testing [Ref. 57]. The use of a single fuel

consumption rate for all variants appears to be the only choice even though there may be differences in vehicle weight as discussed in Chapter II.

In March 1998, the 1st Marine Division (1st MARDIV) published its current edition of the "Redbook." The Redbook is a guide to use when budgeting for events and the principles used in its development are based on actual field operations conducted by the 1st MARDIV. In the Redbook, the fuel consumption rate for the LAV FOV is stated to be 5.26 mpg [Ref. 58]. However, this conflicts with the manufacturer's fuel consumption rate of 4.8 mpg and the NCCA's implied average consumption rate of 5.8 mpg discussed in Chapter III. This computes to an average consumption rate 5.3 mpg between the two extreme measures. This is almost equal to the Redbook average. Thus, for the purpose of this thesis, the fuel consumption rate of 5.26 miles per U.S. gallon is used to represent the "average" fuel consumption rate for all variants regardless of weight, terrain and vehicle aerodynamics. The consumption rate of 5.26 mpg will be used for all fuel cost calculations because the author believes that it best reflects the most probable consumption rate for actual field operations.

The U.S. Government obtains diesel fuel from local fuel distributors under contract for a negotiated price per gallon. The price per gallon of diesel fuel may vary according to the price at the time of contract negotiation as well as geographical location of the negotiation. For planning purposes, the 1998 Redbook estimates that the average price for a gallon of diesel fuel is $.79 per

gallon [Ref. 59]. Therefore, for the purpose of calculating the LAV fuel costs, this figure will be used in this thesis. To calculate the cost per mile for fuel consumption, the $.79 price per gallon is divided by the mpg rating of 5.26. The resulting fuel cost, $.15 per mile, is then multiplied by the number of miles driven to provide an overall cost for fuel usage by the LAVs.

G. PRESERVATIVES, OILS AND LUBRICANTS (POL)COSTS

Another direct, variable cost associated with vehicle maintenance is the replacement of POLs during the performance of scheduled and unscheduled maintenance tasks. The Redbook contains an estimate for the cost of LAV POLs, which excludes all POLs except engine oil, gear oil and automotive/artillery grease (GAA). The estimate is based on an average of 200 miles driven per day for the LAV-25, LAV-AT, LAV-M and LAV-L and 100 miles driven per day for the LAV-C2 and the LAV-R.

The cost of engine oil, gear oil and GAA per mile of operation for the LAV-25, LAV-AT, LAV-M and LAV-L variants is 2.4 cents, .43 cents and 1.1 cents respectively and the costs for the same POLs per mile of operation is 2.5 cents, .43 cents and 1.1 cents respectively for the LAV-C2 and LAV-R [Ref. 60]. It was beyond the scope of this thesis to verify these Redbook estimates for a cost that is not a significant percent of total operating costs. Therefore, FY98 POL costs and FY96 mileage will be used to calculate LAV POL costs because they represent the most recent data available in each category.

The exclusion of additional LAV POLs from the Redbook model presents difficulties in obtaining accurate POL cost estimates. The POLs required by LAV Lubrication Instructions but excluded from the Redbook include hydraulic fluid (FRH), aircraft instrument grease (GIA), wide temp range grease (WTR), gear oil (GO), brake fluid, cleaning solvent as well as cleaner, lubricant and preservative (CLP). The cost associated with these POLs will be captured in the Planning & Estimating (P&E) cost category.

H. IROAN COSTS

The Inspect, Repair Only as Necessary (IROAN) Program, which is also known as Depot Maintenance, was developed to restore Fleet Marine Force (FMF) LAVs to a serviceable condition. IROAN is defined as "That maintenance technique which determines the minimum repairs necessary to restore equipment, components, or assemblies to prescribed maintenance serviceability standards by utilizing all available diagnostic test equipment and test procedures in order to minimize disassembly and parts replacement [Ref. 61]. IROAN costs are classified as direct, variable costs of the variant fleet for the purpose of this thesis.

LAVs are scheduled by major subordinate command (MSC) for IROAN in five-year intervals. This method allows for all LAVs in the Marine Corps, with the exception of pre-positioned LAVs, to go through IROAN every five years. When units send LAV variants through the IROAN Program, they are exchanged

on a one-for-one basis. Variants are inspected and repaired on an as-needed basis and the commands are billed for parts and labor.

Table 4.12 details the I MEF IROAN costs for FY92 through FY96 by variant as well as a FY average [Ref. 62]. The total variant cost is calculated by multiplying the average cost per variant by the number of vehicles. The average annual cost is calculated by dividing the total cost by five.

Table 4.12. LAV IROAN Costs per Vehicle

VARIANT	FY 92	FY 93	FY 94	FY 95	FY 96	AVERAGE	# VEHICLES	TOTAL
LAV-AT	$119,367	$149,519	$158,280	$212,570	$190,888	$166,125	28	$4,651,494
LAV-C2	104,171	106,657	110,658	148,612	133,454	120,710	15	1,810,656
LAV-25	102,340	69,809	91,600	123,019	110,471	99,448	106	10,541,467
LAV-L	104,404	95,610	100,609	135,119	121,337	111,416	31	3,453,890
LAV-M	95,779	100,984	105,984	142,337	127,818	114,580	14	1,604,126
LAV-R	103,692	100,801	116,801	156,864	140,864	123,804	28	3,466,523
							I MEF TOTAL	$25,528,156
							AVG ANNUAL	$5,105,631

I. PLANNING AND ESTIMATING COSTS

Planning and Estimating (P&E) costs are indirect, variable costs, such as administrative supplies and items obtained through the open purchase program that are incurred by the LARs. The open purchase program enables a LAR to purchase goods and services that are not available through normal supply channels. P&E costs are tracked by the fiscal section of the respective LAR Supply Departments and are published in the unit's budget execution report. P&E costs constitute actual dollars amounts committed by the U.S. Government to pay

contractors for goods and services. P&E costs include the costs associated with POL usage.

The P&E costs presented in this thesis have had the average POL costs calculated above deducted. Table 4.13 depicts P&E costs incurred by the 1st and 3rd LARs for FYs 1992 through 1996. P&E costs have been allocated to the respective variant class based on vehicle percentages calculated in Table 4.1. The per mile cost of P&E has been calculated by dividing the average miles driven by the total P&E cost allocated to the variant class.

Table 4.13. I MEF P&E Costs

FY 92	FY 93	FY 94	FY 95	FY 96	AVERAGE
$284,825	$294,314	$276,102	$248,604	$270,052	$274,779

J. DEPRECIATION

Depreciation of assets is one method that can be used to estimate the amount of physical capital that is consumed over time. The principle of straight-line depreciation, where an equal amount of the asset's cost is deducted over a number of periods during the life of an asset, will be applied to the LAV assets within I MEF. The life expectancy for LAV assets is twenty years. Table 4.14 depicts the annual straight-line depreciation costs for I MEF LAV assets. Depreciation is a direct, fixed cost of each variant that will be allocated as an operating cost using the number of miles driven as the baseline. An alternative view is that depreciation is a sunk cost so that the entire cost of the vehicle is

consumed upon procurement. This thesis will present two separate cost models that apply these methods to the total operational cost of the LAV.

Table 4.14. I MEF Depreciation Schedule

VARIANT	UNIT COST	QTY	TOTAL	LIFE	COST/YEAR
LAV-25	$900,000	106	$95,400,000	20	$4,770,000
LAV-AT	1,250,000	28	35,000,000	20	1,750,000
LAV-C2	650,000	15	9,750,000	20	487,500
LAV-L	634,000	31	19,654,000	20	982,700
LAV-M	667,000	14	9,338,000	20	466,900
LAV-R	702,000	11	7,722,000	20	386,100
TOTAL			$176,864,000		$8,843,200

K. MISCELLANEOUS COSTS

The miscellaneous cost category defines all costs associated with the operation of I MEF LAV assets that have not yet been considered. All miscellaneous costs represent indirect, variable costs that are incurred by the I MEF during LAV operations. These costs include training and environmental compliance and are presented in this thesis as budgeted costs vice actual costs. Miscellaneous costs have been allocated to the respective variant class based on vehicle percentages calculated in Table 4.1. The data for this category has been derived from the annual budget requests from the 1st LAR. The assumption that these budgeted amounts represent average actual costs that will be incurred and that they represent 3rd LAR budget estimates is made. The amount of $250,000 will be used to represent average miscellaneous costs incurred by 1st and 3rd LARs.

L. COST FINDINGS

The first research question concerns the estimation of the total overall operating cost, per mile driven, for the LAV. However, as noted above, personnel and depreciation costs present alternative costing issues. In an effort to illustrate the affect that personnel and depreciation have on the total operational cost of the LAV, a full costing approach, which considers all costs, and a material costing approach, which considers only verifiable direct costs, will be used.

The cost summary in Table 4.15 represents the combination of all cost categories discussed above for I MEF LAV assets based on a full costing approach. This is a very common costing approach used in the private sector. The data reveals that the cost of operating the LAV FOV is $19.38 per mile driven with personnel costs representing 72 percent of total costs, depreciation costs representing 14 percent of total costs and IROAN costs representing 9 percent of total costs. Combined, these three items represent 95 percent of the total cost associated with LAV operations. However, a stark difference is noted when operational costs are calculated using the material costing approach. Table 4.16 depicts that the total operational cost per mile driven for the LAV FOV based on the material costing approach. The operational cost drops sharply to $2.68 per mile driven with IROAN costs representing 57 percent of total costs and with parts representing 30 percent of total costs. Combined, these two categories represent 87 percent of the total cost of LAV operations. It should be noted that these

figures represent the average cost of operation for the 205 LAV assets within I MEF and is not representative of the cost to operate the individual variants.

The next research questions concerned the determination of the cost categories that should be included in the estimation of LAV operational costs as well as whether to classify those cost categories as direct or indirect costs.

Table 4.15. I MEF Full Cost per Mile Driven

CATEGORY	COST	AVG MILES	COST/MILE	% OF TOTAL COST
PARTS	$2,668,366	3,333,806	0.80	.04%
PERSONNEL	46,847,495	3,333,806	14.05	72%
FUEL	0.79	3,333,806	0.15	.01%
POL	0.0393	3,333,806	0.0393	.002%
IROAN	5,105,633	3,333,806	1.53	.08%
P&E	274,779	3,333,806	0.082	.004%
DEPRECIATION	8,843,200	3,333,806	2.653	14%
MISC.	250,000	3,333,806	0.075	.004%
TOTAL/MILE			$19.38	100%

Table 4.16. I MEF Material Cost per Mile Driven

CATEGORY	COST	AVG MILES	COST/MILE	% OF TOTAL COST
PARTS	$2,668,366	3,333,806	$0.80	30%
FUEL	0.79	3,333,806	0.15	6%
POL	0.0393	3,333,806	0.0393	1.5%
IROAN	5,105,633	3,333,806	1.53	57%
P&E	274,779	3,333,806	0.082	3.1%
MISC.	250,000	3,333,806	0.075	2.8%
TOTAL/MILE			$2.68	100%

Table 4.17 depicts the cost categories that were determined to contribute significant costs towards the operation of the individual LAV variants based on the

full costing approach as well as the cost type associated with that cost category. Within the cost type category, the letters "D," "I," "V" and "F" annotate direct, indirect, variable and fixed costs respectively.

Table 4.17. I MEF Full Cost Findings by Variant

	COST TYPE	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
PARTS	D.V.	$1,788,826	$358,136	$197,758	$96,702	$147,425	$79,519	$2,668,366
PERSONNEL	D.F. & I.F.	24,223,587	6,398,681	7,084,257	3,199,338	3,427,865	2,513,767	46,847,495
FUEL	D.V.	222,425	36,130	13,185	50,328	29,197	31,505	382,770
POL	D.V.	58,275	9,466	3,458	13,186	7,844	8,464	100,694
IROAN	D.V.	2,108,298	930,300	690,779	320,824	362,130	693,302	5,105,633
P&E	I.V.	142,080	37,531	41,552	18,765	20,106	14,744	274,778
DEPRECIATION	D.F.	4,770,000	1,750,000	982,700	466,900	487,500	386,100	8,843,200
MISC	I.V.	129,268	34,146	37,805	17,073	18,293	13,415	250,000
TOTAL COST		33,442,759	9,554,390	9,051,494	4,183,116	4,500,360	3,740,816	67,024,833
MILES		1,482,834	240,867	87,990	335,521	194,649	210,036	2,551,897
# VEHICLES		106	28	31	14	15	11	
TOTAL/MILE		$22.55	$39.67	$102.87	$12.47	$23.12	$17.81	

The data reveals an operational cost between a low of $12.47 per mile driven for the LAV-M and a high of $102.87 per mile driven for the LAV-L. There is no correlation between the cumulative cost categories and the overall operational cost per variant. The LAV-25 has the highest costs of all variants in all categories, yet it is only the 4th most expensive variant to operate. On the other hand, the LAV-L, which holds varying cost rankings in the cost categories, is the most expensive variant to operate. Examination of all variables has not revealed a pattern among the cost categories from which to predict total variant operating cost.

However, certain individual cost categories show some levels of correlation. The data shows a correlation between the miles driven by a variant and the total cost to operate the variant. For example, the LAV-25, with 106 vehicles, has the highest total operational cost of all variants and the LAV-R, with 11 vehicles, has the lowest total operational cost of all variants. Table 4.4 also shows this correlation on a per vehicle basis. This correlation holds true for all variants except the LAV-AT and the LAV-L. This difference could be explained by the higher depreciation cost for the LAV-AT.

Table 4.18 depicts the cost categories and corresponding cost types that were determined to contribute significant costs towards the operation of the individual LAV variants based on the material costing approach.

Table 4.18. I MEF Material Costs Findings by Variant

	COST TYPE	LAV-25	LAV-AT	LAV-L	LAV-M	LAV-C2	LAV-R	TOTAL
PARTS	D.V.	$1,788,826	$358,136	$197,758	$96,702	$147,425	$79,519	$2,668,366
FUEL	D.F.	222,425	36,130	13,185	50,328	29,197	31,505	382,770
POL	D.V.	58,275	9,466	3,458	13,186	7,844	8,464	100,694
IROAN	D.V.	2,108,298	930,300	690,779	320,824	362,130	693,302	5,105,633
P&E	I.V.	142,080	37,531	41,552	18,765	20,106	14,744	274,778
MISC	I.V.	129,268	34,146	37,805	17,073	18,293	13,415	250,000
TOTAL COST		4,449,172	1,405,709	984,537	516,878	584,995	840,949	67,024,833
MILES		1,482,834	240,867	87,990	335,521	194,649	210,036	2,551,897
# VEHICLES		106	28	31	14	15	11	
TOTAL/MILE		$3.00	$5.84	$11.19	$1.54	$3.01	$4.00	

The table reveals a sharp drop in operational cost from a high of $11.19 for the LAV-L and a low of $1.54 for the LAV-M. As with Table 4.17, the only apparent correlation in the data is between the miles driven by a variant and the

total operational cost. However, in the case of material costing, the correlation does not hold true for the LAV-M, LAV-AT and the LAV-L. One explanation for this lack of correlation is the degree of variance in parts costs, IROAN costs and vehicle quantity.

The final research question concerns the proper allocation method for the indirect costs associated with LAV operation. For this thesis, indirect P&E and miscellaneous costs were allocated based on the percentage of vehicles per variant as compared to the total number of I MEF LAV assets. These percentages, by variant, are presented in Table 4.1. The correlation between indirect cost categories and number of vehicles is present due to this allocation method.

M. SUMMARY

This chapter discussed the cost elements that contribute to the overall operating cost of the LAV FOV as well as individual LAV variants. A cost per mile driven was calculated for the LAV FOV and the individual LAV variants based on a full costing and a material costing approach. The next chapter will present the thesis summary, conclusion and recommendations for future research.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The fiscal restraints placed on the Marine Corps by a continually shrinking defense budget have increased the need for a comprehensive analysis of the cost to operate ground combat systems like the LAV. This thesis focused on presenting an analysis of the various cost components that influence the overall operational cost of the LAV FOV and individual variants per mile driven utilizing a full costing and a material costing approach. The information contained in this thesis is presented to assist commanders with budgeting and cost reduction measures.

In Chapter I, an overview of the origin of the roles and missions of the DOD, United States Marine Corps and the LAV was presented as they relate to the NSS and the NMS.

In Chapter II, a discussion of the various Government agencies that are responsible for defining the roles and mission of each service branch was presented as was the roles and missions delegated to the United States Marine Corps by those agencies. Additionally, a discussion of the previous research and data availability on the subject of LAV operational costs was presented along with an explanation of the organizational structure of a typical LAV unit. Lastly, a detailed discussion of the characteristics of the LAV variants was presented.

In Chapter III, a detailed overview of the various aspects of research methodology was presented in an effort to define the approach, mode and methodology used in the preparation of this thesis.

Chapter IV presented the various elements considered while formulating the overall cost of operating the LAV FOV and individual variants per mile driven. The discussion began with a presentation of the number of LAVs assigned to I MEF by variant and then offered a calculation of the actual and average miles driven by each variant. Next, a discussion of the costs associated with parts replacement, personnel compensation, fuel consumption, POL consumption, IROAN utilization, P&E application, depreciation and miscellaneous costs was presented. Finally, a cost summary that defined the cost to operate the LAV FOV as well as the individual variants per mile, based on the above parameters, was presented utilizing a full costing and a material costing approach.

B. CONCLUSIONS

This thesis attempted to establish a reliable cost estimation model to predict the total cost per mile of operation for the LAV FOV and individual LAV variants. Numerous cost drivers, such as parts, personnel and depreciation, were selected on the basis of available data and the level of contribution to the overall LAV operational cost. The research revealed that, limited to the cost elements presented in this thesis, the overall average cost of operation for the LAV FOV was calculated to be $19.38 per mile driven based on the full costing approach and

$2.68 per mile driven based on the material costing approach. However, the average cost to operate the individual variants per mile varied from a low of $12.47 per mile driven for the LAV-M to a high of $102.87 per mile driven for the LAV-L when utilizing the full costing approach. Likewise, the average cost to operate the same variants dropped significantly to a high of $11.19 per mile driven to a low of $1.54 per mile driven when using the material costing approach. The sharp decline in operational cost between the approaches is due to the high costs of personnel and depreciation. The variance between total LAV FOV costs and total individual variant costs suggests that the variant method provides a more accurate assessment of operating costs than the FOV method.

Additionally, the cost drivers selected were classified as either direct or indirect costs as well as either variable or fixed costs. All costs, with the exception of indirect costs, were allocated on the basis of miles driven. Indirect costs were allocated based on the percentage of vehicles per variant as compared to the total number of I MEF LAV assets. The limitations of indirect personnel as well as 3rd and 4th echelon maintenance costs would certainly add to the overall operational cost of the LAV FOV and individual variants. Understanding the costs associated with 3rd and 4th echelon maintenance and indirect personnel would reveal a more accurate overall operational cost.

C. RECOMMENDATIONS

1. Recommend further research be conducted to enable the accurate identification of direct personnel costs to each variant to include with material costs in a direct costing model.

2. Recommend that the Force Service Support Group continue to allocate 3rd and 4th echelon maintenance and personnel costs to the individual LAR and that those costs be incorporated into the MOSIS cost report.

3. Recommend that further study be conducted in the application of personnel costs based on the discrepancies found when comparing the T/O manpower levels with Alpha Roster manpower levels to determine the best approach in allocating such costs.

4. Recommend that efforts expended in the tracking of POL costs be increased to include all POL listed in the LIs.

5. Improve the practice of legibly recording fuel purchases so that accurate fuel cost can be gathered by variant.

6. Establish a benchmark for each category and monitor future costs per mile driven for cost efficiencies.

7. Gather comparative data from similar U.S. Forces or Allied Countries' forces to highlight cost differences.

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